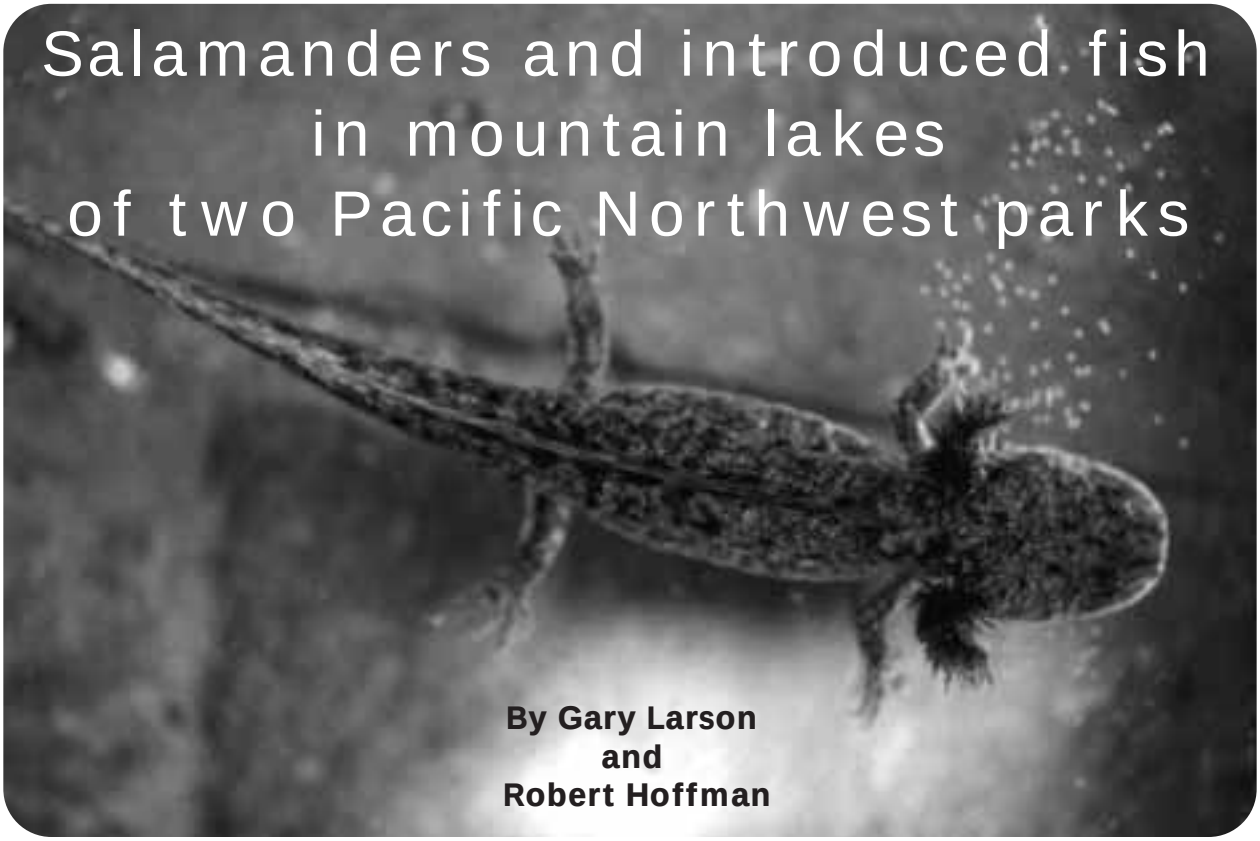
Salamanders and introduced fish in mountain lakes of two Pacific Northwest parks



By Gary Larson and Robert Hoffman

During the last century, many fishless mountain lakes in the Pacific Northwest were stocked with nonnative fish, such as brook trout, for recreational purposes. The introduced fish replaced native salamander larvae as the top aquatic vertebrate predator in these lakes. To understand the impact of the fish on the salamanders, we investigated the abundance of larvae in mountain lakes where nonnative fish had been introduced. At Mount Rainier National Park and North Cascades National Park Service Complex (which includes Ross Lake and Lake Chelan National Recreation Areas, in addition to North Cascades National Park), we surveyed previously fishless lakes that had been stocked, and lakes without fish. (For more information on survey methodology, see Hoffman et al. 2003. Habitat segregation of *Ambystoma gracile* and *Ambystoma macrodactylum* in mountain ponds and lakes, Mount Rainier National Park, Washington. Journal of Herpetology 37:24–34.) The studies suggest that two salamander species are affected quite differently by the introduction of fish because of differences in the distributions, life history characteristics, and habitat requirements of the two species.

Figure 1. Typical larval form of the northwestern salamander.
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The two salamander species studied were the long-toed salamander *(Ambystoma macrodactylum)* and the northwestern salamander (*Ambystoma gracile,* fig. 1). We found greater abundances of larvae of both species in fishless lakes (fig. 2). Also, we found that when fish are present in a lake, larvae of both species restrict their daytime activity to nearshore areas where much bottom cover (such as

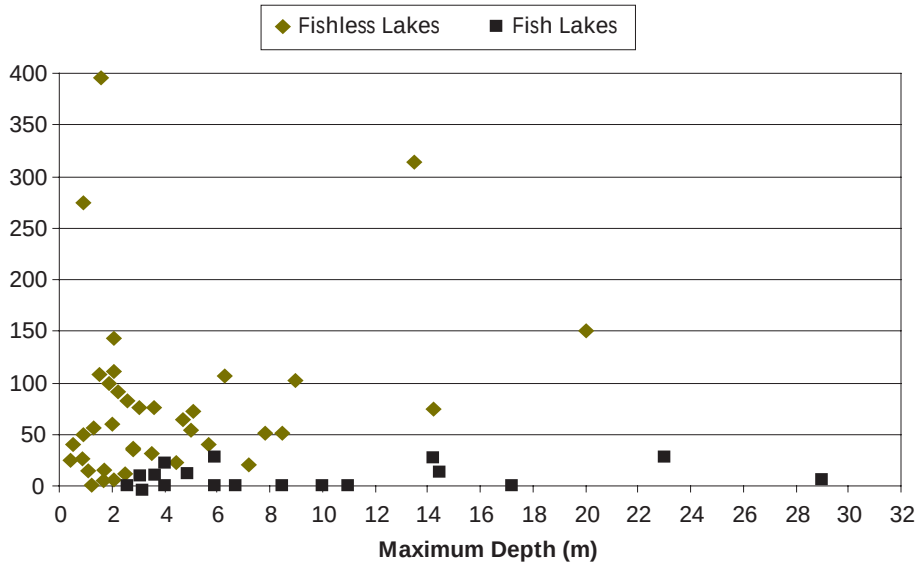

Figure 2. The number of salamander larvae observed per 100 m surveyed in Mount Rainier National Park ponds or lakes that have fish or are fishless. (Depths are maximums.)

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submerged logs and tree branches) is available, and they are primarily active at night. To evaluate the finding that introduced fish affect salamander abundance and behavior, we removed fish from a small lake in Mount Rainier National Park that had a population of northwestern salamander larvae. The fish were removed over a period of six years, with most removed within the first two years. Once fish were removed, the total number of larvae observed (fig. 3), and the proportion of larvae observed offshore compared to nearshore, increased during daytime surveys.

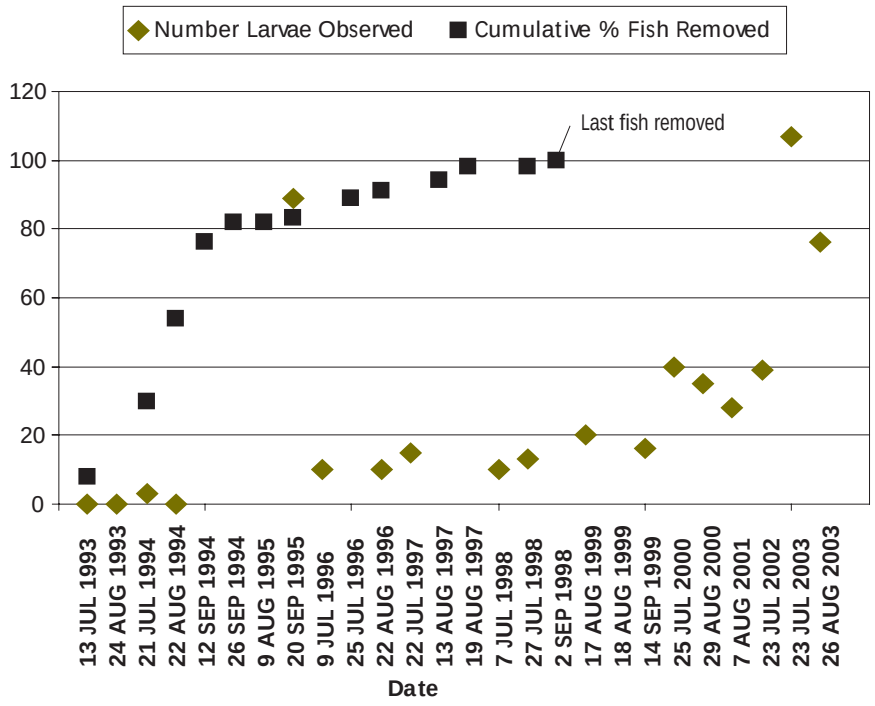

Figure 3. The number of salamander larvae observed per 150 m surveyed during daytime in Mount Rainier National Park increased from 1993 through 2003 when fish were removed from the lake.

Experiments conducted in artificial ponds to investigate trout predation on northwestern and long-toed salamander larvae have shown that both species suffer reduced abundance because of predation by trout. These results are borne out by examination of feeding habits of introduced fish in natural lakes. The two salamander species have different life-history characteristics, however, which is one factor that affects the way each species responds to the presence of fish. Northwestern salamanders in mountain lakes typically reach reproductive maturity without transforming into terrestrial adults. These individuals are known as neotenes or aquatic gilled-adults. Neotenes can grow to be more than 7 inches (175 mm) in total length, which is as large as many of the trout in the lakes, and they tend to be less vulnerable to predation by the trout. Since neotenes and smaller larvae cannot survive on land and are therefore restricted to the lakes they inhabit, individuals that coexist even at low abundance with introduced fish alter their behavior to reduce their interaction with the fish. In these lakes, northwestern salamanders are very secretive and remain hidden during the daytime when they are more vulnerable to predation by trout.

Long-toed salamanders do not have the aquatic gilled-adult life-stage and must transform into terrestrial adults. As terrestrial adults, they can leave lakes that have fish and limit their reproductive activity to fishless lakes and small shallow ponds if these sites are located relatively close to the lakes from which they emerge. If fishless lakes and ponds are not available, terrestrial adults will continue to reproduce where fish are present and may be eliminated from these lakes. Although terrestrial adults can grow to more than 6 inches (150 mm) in total length, larvae are much smaller at the time of metamorphosis (1.75-in or 48-mm snout–vent length) and are vulnerable to trout predation. Long-toed salamanders that are occasionally found at low abundance in lakes with fish are present only in the structurally complex shallow areas of the lakes where they can, like northwestern salamanders, more easily escape predation.

The two species also have different distributions and habitat requirements that affect their vulnerability to fish. Northwestern salamanders are primarily found in lakes greater than 7 feet (2.1 m) deep, that is, in lake basins that do not fill to the bottom with ice and snow in winter. Long-toed salamanders live in both deep and shallow lakes and ponds. Recent evidence suggests that when northwestern salamanders are present, they exclude the long-toed species from the deep lakes. Thus, the depth of the water and the interaction between salamander species determines which one is present and which will be impacted by the introduction of the fish.

At Mount Rainier National Park both species are present. The long-toed salamanders occupy lakes less than 7 feet (2.1 m) deep. Fish usually cannot survive in such shallow water; therefore, at this park, long-toed salamander larvae are rarely affected by introduced fish. The northwestern salamanders occupy the deeper lakes where fish are present and so are impacted by them.

At North Cascades National Park Service Complex, the distribution of northwestern salamanders is more limited than at Mount Rainier: No northwestern salamanders are found on the eastern side of the hydrologic divide of the Cascades Range, and relatively few populations occur west of the divide because this is the easternmost extent of their range. Thus, the long-toed salamander is able to inhabit both deep and shallow lakes and ponds east of the divide. West of the divide the same is true, except in the occasional deep lakes where northwestern salamanders occur. This widespread distribution means that the long-toed salamanders are more likely to be impacted by the introduced fish than the relatively uncommon northwestern salamanders.

This study underscores the importance of developing separate management strategies for each salamander species based on its life history characteristics, habitat requirements, and vulnerability to fish impact. Resource managers need to be aware of the distribution patterns of the salamanders and introduced fish in the parks, especially as the distributions relate to lake size, depth, and habitat. Since the National Park Service has ended the stocking of lakes with fish almost entirely, the fish in some stocked lakes have become extinct. However, fish still remain in lakes where they have achieved a level of reproductive success. These are the lakes that should be of concern to managers when developing strategies for the maintenance of native larval salamander populations, or strategies for the recovery and restoration of sensitive and threatened native salamander species. The removal of fish from lakes in areas where these species occur could be an important management objective. For managers on other montane lands who stock fish, knowing the distributions of native salamander species could influence which lakes are stocked. Understanding how introduced fish impact aquatic ecosystems and how larval salamanders and other amphibians are affected and respond to the presence of fish can help managers support and monitor the ecological integrity of these ecosystems.

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To help manage the volume of information on nonnative species, we created the Invasive Species Information Node as part of the National Biological Information Infrastructure—a broad, collaborative program to provide increased access to data and information on the nation's biological resources (see http://www.nbii.gov/). When fully operational, the Invasive Species Information Node will:

- Evaluate the invasion of multiple biological groups (and several invasive species) simultaneously, relative to habitat and ecosystem maps, land-use maps, and "change detection" satellite information and models.
- Zoom in on particular states, parks, refuges, and natural areas by merging data sets from many sources into single, dynamic representations of the highest priority problem species and problem areas.
- Access invasive species information and models on local, state, regional, and national scales.
- Quickly assess vulnerability to invasion, current invasions, potential spread of species, natural barriers to invasion, and the economic and ecological effects of invasive species.

The node will increase accessibility of data, accelerate the sharing of information, and promote the use of predictive modeling in developing strategic, proactive approaches to invasive species containment and control. Specifically for the National Park Service, we will assist in evaluating local, regional, and national patterns of control efforts by the Exotic Plant Management Teams. By mapping the location of target species in relation to derived environmental data (e.g., slope, aspect, elevation, and community type), we will be able to quantify patterns of current invasion and probable distributions of priority species, as well as assess the vulnerability of habitat types to invasion. Immediately summarized data and models will help guide strategic control and restoration strategies.

The core aspect of our work is sharing data and information, which will improve predictive modeling. Sharing data and information promotes a proactive rather than reactive approach to the management of invasive species. The USGS National Institute of Invasive Species Science and National Biological Information Infrastructure are committed to the long-term delivery of unbiased, scientific data in support of resource management of public lands.

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